REMARKS/ARGUMENTS

Claims 1 – 3 and 5 – 17 remain pending in this application. Claim 4 has been canceled. Claims 18 – 27 have been withdrawn, but applicants retain the right to present those withdrawn claims in one or more divisional applications in view of the examiner's earlier restriction requirement.

Turning now to the rejections set out in the action, claims 1 – 4 were rejected under 35 U.S.C. 103(a) as being unpatentable over the Brown patent in view of Arnold. The examiner viewed Brown as teaching pyrolyzing rubber to obtain volatiles and residual char, and thereafter pulverizing that char to produce an ultrafine powder having a particle size in the 3 to 15 micron range. Arnold is that patent cited in applicants' specification.

Note first that the retorting conditions originally presented in dependent claim 4 have been incorporated by amendment into claim 1 and those limitations are now included within all of the pending claims. All pending claims now require that the discarded rubber be pyrolyzed in an externally heated, closed retort at a temperature in the range 450° to 650° C until emission of volatiles ends. In a practical operating sense, that requires a cycle time in the retort of about 3 hours or more at a temperature approaching or exceeding about 500° C. Brown's rubberized carbon product, or any other rubber for that matter, simply cannot survive the retorting conditions required by applicant's claim 1.

The carbon product obtained by Brown is in no sense the same as the char as defined in applicants' claim 1. Brown's carbon product contains rubber; applicants' char does not. Brown describes his carbon product as "spherical rubberized particles (particles of carbon black encapsulated in spheres of rubber) in a useful range of 1-60 microns". (column 2, lines 2-4). Brown's rubberized carbon product is made by passing small particles of waste rubber that contain carbon black through a rotating, tubular retort held at a preferred temperature in the range of 500° to 850° F (which is about 260° to 455° C) for a dwell time within the retort of "approximately 35-40 seconds", and that dwell time "is critical to the proper formation of spherical rubberized carbon black". (column 3, lines 11-13) The

retorting time required to produce applicants' char product is typically more than 100 times the "critical" dwell time required by Brown, thus showing a clear difference in kind between Brown's rubber product and applicants' char product.

The examiner further asserts that Brown subjects his "char" (actually not char at all but an admixture of rubber and carbon black) to pulverization to produce a powder product having a particle size of 3 – 15 microns (citing col. 3, lines 23 – 30). That passage is both ambiguous and contradictory. Brown's carbon product is sized by passing it through a series of screens 19 "and preferably sized between 80-40 screen fineness" (col. 3, lines 39-41). Applicant is enclosing as Exhibit A a sieve Comparison Table prepared by the International Starch Institute, Science Park, Aarhus, Denmark. As is set out therein, a sieve of 80 U.S. Mesh market grade screen cloth has openings that are 180 micrometers in width while a sieve of 40 U.S. Mesh market grade screen cloth has openings that are 380 micrometers in width. The finest sieve listed in the extensive compendium of Exhibit A is a 400 mesh wire cloth twilled weave having openings that are 38 micrometers in width.

If the interpretation of the Brown patent that is assumed by the examiner is to be considered correct—that Brown obtains a particulate product having a size range below 15 micrometers in diameter by sieving—then one must first assume that sieves of sufficient fineness to produce such a result exist. Nothing in the literature known to applicant even suggests that sieves finer than 400 mesh (openings of 38 micrometers in width) exist today. If the examiner holds to the interpretation of Brown's teachings set out in the action—that Brown's use of the term "screen fineness" refers to the particle size in microns rather than to screen mesh—then it is respectfully requested that the examiner cite references showing the existence of the15 micron sieves that would be required to carry out that version of the Brown process.

Filters, rather than sieves, are routinely used to remove particulates in the 3 – 15 micron size range from either gases or liquids. Excerpted pages from the Millipore Catalog are enclosed as Exhibit B to illustrate that point. See, for example, Millipore filter Grade 224 (page 2 of the catalog) which retains particles larger than

16 microns. That particular filter takes a long time, 140 seconds, to pass 100 ml of liquid through a 10 square cm area under a 10 cm head pressure, see the data presented on page 3 of the catalog. As was noted on page 2, lines 18 – 21 of applicants' specification, the grinding of char requires production of a very fine and abrasive product at rates of one ton or more per hour on a continuous basis in order to be economically viable. Those data and practical considerations further illustrate the total impracticability of sieving or filtering particulates to obtain a 3 – 15 micron product.

Brown's grinding device 14 is described in the patent as a "pulverizer or crusher" and, applicants submit, a standard grinding device such as a rod or ball mill would be among those contemplated by Brown for that purpose. Applicants are enclosing as Exhibit C an excerpt from a standard handbook that illustrates the results one might expect in grinding a hard material, such as an ore, using a standard rod mill or ball mill. It is fair to presume that such a standard grinding device as a rod or ball mill would be among those contemplated by Brown in his disclosed process for use as the pulverizer or crusher 14. Exhibit C is taken from:

Chemical Engineers' Handbook, 4th Edition; John H. Perry
McGraw-Hill, pages 8-23 to 8-25 (1963)

See particularly the reported performance data wherein the finest grind shown in the data is 325 mesh. Now compare those data to the results presented in applicant's example II. There simply is no equivalence. Those considerations lead one to an inevitable conclusion that the Brown process, as it has been interpreted in the examiner's action, has no reasonable expectation of success. That sort of teaching cannot stand as a teaching of obviousness, but supports instead a conclusion of nonobviousness; see the case of *In re Reinhart, 189 USPQ 143 (CCPA 1976).*

A patent to Fader, U.S. 5,037,628, was discussed as related prior at page 2 of applicants' specification, and that patent was cited to the Office in applicants' Information Disclosure Statement. The teachings contained in that patent are relevant here. Quoting from Fader:

> Attempts have been made in the past to reduce the char particle size such that a more commercially acceptable grade of carbon black could be obtained. A fluid energy mill process has been used to pulverize the char particles to produce a finer particle size by way of implosion of all particles in the char material. Such a process is shown in U.S. Pat. No. 3,644,131 issued to Gotshall. These processes will produce in the one to ten micron range of char particles. However, the capital, expenditure and operating expenses for set up and operation, and the high amounts of energy cost required for use of such a process in production make the resulting product too expensive for normal scaled production. (Column 2, lines 32 – 44)
>
> In other attempts for refining the char material, a roller grinding mill similar to the type used to grind coal particles into fine particles for combustion etc. have been used in reducing the char particles. However, with this method the particle size is limited to about a 325 mesh or 45 micron bulk product. (Column 2, line 64 – column 3, line 1)

The examiner's rejection of the claims as being unpatentable over Brown in view of Arnold rests on a number of assumptions. The first of those assumptions is that Brown's rubberized carbon black is the same as, or equivalent to, applicants' char. That assumption is clearly in error for the reasons that have been detailed earlier in this response. The second assumption is that Brown's "crusher or pulverizer" (element 14) operates in reality to produce a product having a particle size range of about 3 to 15 microns. Acceptance of that assumption requires first a finding that sieves 12 are capable of sizing the ground product to recover a minus 15 micron product and requires second that one reject the teachings of applicants' Exhibits A, B, and C, and to reject as well the clear teachings of the Fader patent quoted directly above. Applicants submit that the overpowering weight of the evidence serves to hold that Brown's ambiguous and contradictory disclosure properly should be interpreted as referring to screen mesh designations rather than to particle size. Finally, the rejection requires one to assume that the resonance disintegrator is essentially equivalent to the generic "crusher or pulverizer" of Brown. There is absolutely no support in the cited references for that assumption as there is no suggestion of any kind—outside of applicants' own disclosure—that resonance disintegration produces results in the grinding of char that are unobtainable using traditional crushers and pulverizers. That consideration alone refutes any *prima facie* case for obviousness.

This is a situation where the teachings of the prior art seem to conflict. The examiner must, in such a situation, consider the teachings of all the prior art and

must weigh the credibility of each reference against the others. See the case of *In re Young,* 18 USPQ2d 1089 (Fed. Cir. 1991). Such weighing, applicants submit, will serve to discredit the Brown disclosure as it relates to particle size of product obtained and so will provide additional grounds for refuting the examiner's case for obviousness.

The remaining claims, 5 – 17 inclusive, are all directed to techniques for subjecting the resonance-disintegrated carbon powder particles to a further treatment that modifies the surface properties of the powder particles. All of those claims have been rejected under 35 U.S.C. 103(a) as being obvious over Brown in view of Arnold and various secondary references that show treatment of carbon or carbon containing materials with various agents. Claims 5 – 17 are all dependent upon claim 1, and if claim 1 is patentable, then all of claims 5 – 17 are likewise patentable. Applicants submit that, in light of the amendments made and arguments and exhibits presented, claim 1 is *prima facie* unobvious and is therefore patentable as are all claims dependent upon claim 1.

Applicants note in passing that the examiner had previously found claim 1 to be patentable if amended to include all of the limitations presented in dependent claims 5, 6, 11, 12, and 13. That finding of patentable subject matter is contained in the proposed Examiner's Amendment dated June 12, 2003, and is a part of the record in this application. The rejection of claims 13 – 17 in the August 8, 2003 action is clearly at odds with the previous finding of allowability.

It is submitted that this amendment and response refutes and obviates all of the rejections of record. Applicants therefore respectfully request that a timely Notice of Allowance be issued in this case.

Respectfully submitted,

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November 13, 2003

International Starch Institute

Science Park Aarhus, Denmark

Sieve Table

Sieve Comparison Table

ISO 565 1987	DIN 4188 1977	US Std/ASTM E-11-1987	Tyler®	BS 410 1986
mm	mm	US Mesh	Mesh	Equivalent BS Mesh
		Inch	Inch	
		3" .		
		2".		
26,5	25	1.06"	1.05".	
25	22,4	1"		
22,4	20	7/8"	0.883"	
19	18	3/4"	0.742"	
16	16	5/8"	0.624"	
13,2	14	0.530"		
12,5	12,5	1/2 "		
11,2	11,2	7/16"	0.441"	
9,5	10	3/8"	0.371"	
	9			
			Mesh	
8	8	5/16"	2.5	
6,7	7,1	0.265"	3	
6,3	6,3	1/4"		
		Mesh		
5,6	5,6	3½	3.5	3
4,75	5	4		3½
	4,5			
4	4	5	5	4
3,35	3,55	6		5
	3,15			
2,8	2,8	7		6
2,36	2,5	8	8	7
	2,24			
2	2	10		8
1,7	1,8	12	10	10
	1,6			
1,4	1,4	14	12	12
1,18	1,25	16	14	14
	1,12			
1	1,0	18	16	16
Microns (μm)	Microns (μm)			
850	900			18

EXHIBIT A

	800	20	20	
710	710	25	24	22
	630			
600		30	28	25
	560			
500	500	35	32	30
	450			
425	430	40	35	36
	400			
355	355	45	42	44
	315			
300		50	48	52
	280			
250	250	60	60	60
212	224	70	65	72
	200			
180	180	80	80	85
	160			
150		100		100
	140			
125	125	120	115	120
106	112	140	150	150
	100			
90	90	170	170	170
	80			
75		200	200	200
	71			
63	63	230	250	240
53	56	270	270	300
	50			
45	45	325	325	350
38	40	400	400	400
	36			
32	32	450	450	440
25	25	500	500	
20	20	635	635	
16	16			
10	10			

Go to Top

MARKET GRADE WIRE CLOTH

MARKET GRADE WIRE CLOTH is woven utilising moderate wire diameters resulting in a high strength square mesh cloth, suitable for general purpose screening. Market Grade wire cloth is woven in Steel, Stainless Steel, Phosphor Bronze, Bronze, Brass, Copper, Aluminium, Monel and Nickel.

Meshes Per Linear Inch	Diameter of Wire		Width of Opening		Open Area

	Inches	mm	Inches	mm	
2 Mesh	0.063	1.60	0.437	11.10	76.4%
3 Mesh	0.054	1.37	0.279	7.09	70.1%
4 Mesh	0.047	1.19	0.203	5.16	65.9%
5 Mesh	0.041	1.04	0.159	4.04	63.2%
6 Mesh	0.035	0.89	0.132	3.35	62.7%
8 Mesh	0.028	0.71	0.097	2.46	60.2%
10 Mesh	0.025	0.64	0.075	1.91	56.3%
12 Mesh	0.023	0.584	0.060	1.52	51.8%
14 Mesh	0.020	0.508	0.051	1.30	51.0%
16 Mesh	0.018	0.457	0.0445	1.13	50.7%
18 Mesh	0.017	0.432	0.0386	0.98	48.3%
20 Mesh	0.016	0.406	0.0340	0.86	46.2%
22 Mesh	0.015	0.381	0.0305	0.78	45.0%
24 Mesh	0.014	0.356	0.0277	0.70	44.2%
30 Mesh	0.013	0.330	0.0203	0.52	37.1%
35 Mesh	0.011	0.279	0.0176	0.45	37.9%
40 Mesh	0.010	0.254	0.0150	0.38	36.0%
45 Mesh	0.0095	0.241	0.0127	0.32	32.7%
50 Mesh	0.009	0.229	0.0110	0.28	30.3%
60 Mesh	0.008	0.203	0.0087	0.22	27.2%
70 Mesh	0.007	0.178	0.0073	0.19	26.1%
80 Mesh	0.0055	0.140	0.0070	0.18	31.4%
90 Mesh	0.005	0.127	0.0061	0.16	30.1%
100 Mesh	0.0045	0.114	0.0055	0.14	30.3%
110 Mesh	0.004	0.102	0.0051	0.129	31.4%
120 Mesh	0.0037	0.094	0.0046	0.1168	30.7%
150 Mesh	0.0026	0.066	0.0041	0.1041	37.4%
200 Mesh	0.0021	0.054	0.0029	0.0737	33.6%
325 Mesh	0.0014	0.036	0.0017	0.043	30.0%

Go to Top

MILL GRADE SCREEN CLOTH

Mill Grade is wire cloth woven of lighter wire diameters than Market Grade, providing a greater percentage of screen cloth open area.

Meshes Per Linear Inch	Diameter of Wire		Width of Opening		Open Area
	Inches	mm	Inches	mm	
2 Mesh	0.0540"	1.37	0.446"	11.33	79.6%
3 Mesh	0.0410"	1.04	0.292"	7.42	76.7%
4 Mesh	0.0350"	0.89	0.215"	5.46	74.0%
5 Mesh	0.0320"	0.81	0.168"	4.27	70.6%
6 Mesh	0.0280"	0.71	0.139"	3.53	69.6%
7 Mesh	0.0280"	0.71	0.115"	2.92	64.8%
8 Mesh	0.0250"	0.64	0.100"	2.54	64.0%
9 Mesh	0.0230"	0.58	0.088"	2.24	62.7%
10 Mesh	0.0200"	0.51	0.080"	2.03	64.0%

12 Mesh	0.0180"	0.457	0.065"	1.65	60.8%
14 Mesh	0.0170"	0.432	0.054"	1.37	57.2%
16 Mesh	0.0160"	0.406	0.0465"	1.18	55.4%
18 Mesh	0.0150"	0.381	0.0406"	1.03	53.4%
20 Mesh	0.0140"	0.356	0.0360"	0.91	51.8%
22 Mesh	0.0135"	0.343	0.0320"	0.81	49.6%
24 Mesh	0.0130"	0.330	0.0287"	0.73	47.4%
26 Mesh	0.0110"	0.279	0.0275"	0.70	51.1%
28 Mesh	0.0100"	0.254	0.0257"	0.65	51.8%
30 Mesh	0.0095"	0.241	0.0238"	0.61	51.0%
32 Mesh	0.0090"	0.229	0.0223"	0.57	50.9%
34 Mesh	0.0090"	0.229	0.0204"	0.52	48.1%
36 Mesh	0.0090"	0.229	0.0188"	0.48	45.8%
38 Mesh	0.0085"	0.216	0.0178"	0.45	45.8%
40 Mesh	0.0085"	0.216	0.0165"	0.42	43.6%
45 Mesh	0.0080"	0.203	0.0142"	0.36	40.8%
50 Mesh	0.0075"	0.191	0.0125"	0.32	39.1%
55 Mesh	0.0070"	0.178	0.0112"	0.28	37.9%
60 Mesh	0.0065"	0.165	0.0102"	0.26	37.5%

Go to Top

FINE MESH WIRE CLOTH TWILLED WEAVES

Meshes Per Linear Inch	Diameter of Wire		Width of Opening		Percent Open Area
	Inches	mm	Inches	mm	
110 Mesh	0.0045"	0.114	0.0046"	0.1168	25.6%
120 Mesh	0.0040"	0.102	0.0043"	0.1092	26.8%
130 Mesh	0.0038"	0.097	0.0039"	0.0991	25.6%
140 Mesh	0.0033"	0.084	0.0038"	0.0965	28.6%
150 Mesh	0.0030"	0.076	0.0037"	0.0940	30.4%
160 Mesh	0.0028"	0.071	0.0035"	0.0889	30.8%
170 Mesh	0.0026"	0.066	0.0033"	0.0838	31.2%
180 Mesh	0.0025"	0.064	0.0031"	0.0787	30.6%
200 Mesh	0.0023"	0.059	0.0027"	0.0686	29.1%
230 Mesh	0.0018"	0.046	0.0025"	0.0647	34.3%
250 Mesh	0.0016"	0.041	0.0024"	0.0610	36.0%
270 Mesh	0.0016"	0.041	0.0021"	0.0533	32.2%
300 Mesh	0.0015"	0.038	0.0018"	0.0457	29.7%
325 Mesh	0.0014"	0.036	0.0017"	0.0432	30.7%
400 Mesh	0.0010"	0.026	0.0015"	0.0381	36.0%

Go to Top

DICTIONARY

absolute micron retention	In both types of Dutch weave the sum derived from multiplying the number of weft wires in a given measurement by their diameter, results, in theory, in a specification with no open space. Because the wires are driven together

	during the weaving process, the aperture size cannot be calculated in the normal manner. There are two methods by which the aperture size can be determined: bubble point testing and glass bead testing. See-"bubble point test" See-"glass bead test"
ACS	American Chemical Society.
AICHE	American Institute of Chemical Engineers
AIME	American Institute of Mining, Metallurgical and Petroleum Engineers.
anneal	A heat-treating process in which the steel is heated to some elevated temperature, usually at or near the critical range and held at this temperature for a period of time, then cooled, usually at a slow rate. Annealing is employed (1) to soften steel for secondary machining or forming processes; (2) to alter ductility, toughness, electrical or magnetic characteristics or other physical properties; (3) to refine the crystal structure; (4) to produce grain reorientation; or (5) to relieve stresses and hardness resulting from weaving (cold working).
annealed after	Wire cloth or wire mesh which is annealed after the weaving process.
annealed wire	Wire which has been cold-drawn to reduce its diameter is often annealed to reduce strength and increase elongation to facilitate weaving.
ANSI	American National Standards Institute.
aperture	The clear opening between wires on a wire mesh screening surface.
ASME	American Society of Mechanical Engineers.
ASTM	American Society for Testing and Materials. ASTM E-11 is the standard most widely used in North America. The opening is defined by a number (number 635 (20 µm) to number 3-1/2 (5.6 mm)) or is defined in inches (1/4 in. (6.3 mm) to 5 in. (125 mm)).
AWCI	American Wire Cloth Institute.
A.W.G.	American Standard Wire Gauge.
AWS	American Welding Society.
backing cloth	Wire mesh or wire cloth which is utilised to provide support for a screen surface.
backing screen	Wire mesh or wire cloth fabricated with or otherwise fastened to (from below) the primary screen surface. See-"support screen".
ball screen	Wire mesh or wire cloth screen placed below the primary screen surface to retain rubber or steel balls or plastic discs which are set in motion by a vibrating screen deck. Ball screens are utilised to reduce or prevent blinding or plugging.
blinding	Filling in and clogging of the wire mesh openings (apertures) due to particle entrapment of the process material. The wire cloth becomes "blind" to the process flow.
BMT	Abbreviation for "Broad Mesh Twilled Dutch Weave"
B lting Cloth	A group of industrial wire cloth specifications, woven in very smooth and durable stainless steel or monel in a plain square mesh pattern. Wire

	diameter is lighter than "mill grade", allowing a high percentage of open area. Bolting cloth is used for wet or dry sifting and separating.
bran duster cloth	Plain weave steel wire cloth of medium mesh sizes produced in market grade diameters. Available in in roll widths of 24", 30", 36" and 48" for use in flour mills.
broadmesh	In broad mesh specifications the warp wire is typically smaller in diameter than the weft wire.
BSI	British Standardisation Institute
bubble point test	The pressure required to pass air bubbles through the mesh (covered by a test liquid) is measured. The average aperture size is then calculated by taking into account surface tension, liquid density, temperature and immersion depth. See- "absolute micron retention" See- "glass bead test"
B.W.G.	Birmingham Wire Gauge.
calendered wire cloth	Wire cloth that has been passed through a set of heavy rollers to reduce the thickness of the cloth or to flatten the wires at weave intersections providing a smooth surface.
Centrisieve	Rotating conical screen typical with a 125 micron screening plate in stainless steel or a finer steel cloth.
clear opening	The space (aperture) between adjacent parallel wires
coarse mesh	Wire cloth having a mesh count of 30 x 30 or less.
count	The number of openings (apertures) in a lineal inch.See- "mesh".
cyclone screener	Cylindrical stationary sieve with rotating paddles flinging the fines through the screen, while the overs leaves the cylinder opposite the inlet.
dewatering	Separation of solids from liquids in which the solids are retained on the screen surface while the liquids pass through the screen (wire mesh or wire cloth) surface.
DIN	German Institute for Standardisation
DTW	Abbreviation for "Dutch Twilled Weave".
Duplex Weave	This specification is similar to a Plain Dutch Weave except that two warp wires are used, rather than one.
Dutch Weave	Wire mesh or filter cloth with warp wires larger than the shute wires. Warp wires remain straight while adjacent shute wires slightly overlap, resulting in a dense, strong material with small irregular, twisting passages that appear triangular in shape when viewing the material diagonally. Dutch weaves have much lower flow rates and much higher particle retention than plain square weaves. See - "Hollander Weave"
filter	A device utilising filter media for particle retention for clarification of a liquid or gaseous fluids.
filter cloth	Wire or synthetic cloth woven with a greater number of wires in one direction than the other, and utilising two different wire diameters. Filter cloth is woven in both plain and twill weave patterns. Also referred to as "Dutch Weave".
filtrati n	The process of clarifying a fluid or gaseous liquid by the removal (retention) of solid particles

fine mesh	Wire cloth having a mesh count greater than 90 x 90
fines	The product passing the sieve. The overs is retained on the sieve.
flat belt vacuum filter	Horizontal filter with a filter cloth moving discontinuously across a vacuum zone
flo ding	The effect created when the screen surface is unable to pass fluids through, in wet screening operations such as washing or dewatering., a result of blinding
Gauge	A term referring to the measure of wire diameter. The Washburn & Moen Gauge is the standard in the manufacture of wire cloth in North America
glass bead test	A suspension containing glass beads is passed through the mesh - the diameter of the largest bead passing through is considered as the absolute micron retention. See - "bubble point test"
Grizzly Screen	Heavy screen cloth usually having a large opening size and made from large diameter high carbon or oil tempered wire or rod.
hard wire	Wire which has been drawn down to a smaller diameter after the annealing process, increasing its unit strength and reducing its elongation.
Hardware Cloth	A square mesh, general purpose galvanised-after plain weave wire cloth.. Made in one wire size only, one for each of several standard meshes. Hardware Cloth is also available in welded construction.
Harp Screen	Screen cloth with long slots, typically 12 inches or longer, for screening high volume tonnage containing a large amount of fines
Hollander Weave	A description applied to woven wire cloth where the diameter of the warp and weft wires, and the mesh count in the warp and weft directions, are different. The wires are driven up much closer during the weaving process, thus producing a more densely compacted weave with small aperture sizes, without reducing the overall cloth thickness. Also referred to as "Dutch Weave".
HP	Hollander Plain Weave.
HT	Hollander Twill Weave.
Hydrocyclone	A liquid-solids separation device utilising centrifugal force for settling.
ICW	Inside clamping width
IWWA	International Wire Weavers Association
inside dimension	(ID) The distance measured between the inner edges of a formed screen panel. Also referred to as "ICW"
ISO	The International Organisation for Standardisation is a worldwide federation of national standards bodies (ISO member bodies). ISO 4782 standard governs metal wire for industrial wire screens and woven wire cloth. ISO 9044 standard governs industrial wire cloth.
KPZ	Reverse Hollander Twill Weave.
long slot	See - "slotted openings"
Market Grade	A group of industrial wire cloth specifications suitable for general purpose screening applications, made of high strength square mesh cloth, available in several types of material. The wire diameters are moderately larger than "mill grade" , with a lower percentage of open area.
medium mesh	Wire cloth having a mesh count of 30 x 30 to 90 x 90 inclusive

mesh no.	This generally denotes the number of apertures in a length of 25.4mm (1"). While it is considered an obsolete designation, it is used extensively.
mesh	Mesh designates the number of openings and fractional parts of an opening, per lineal inch. Mesh is determined by counting the number of openings from the centre of any wire to the centre of a parallel wire, one inch in distance. When the point one inch distant from the centre of a wire falls between wires within an opening, the mesh count is expressed as a fraction.
micron	One micron is equivalent to 0.001mm or 0.00003937 inches. The micron is the unit of measure in the metric system. It is frequently used when referring to the aperture size or particle-retention of filter cloth.
micron retention	Micron retention is defined as the diameter of the largest round particles which can pass through a filter.
Micronic grades	Finer mesh range of Dutch Weave cloth in meshes giving retention of 50 microns or finer.
Mill Grade	Group of industrial wire cloth specifications with lighter wire diameters than "market grade". Standard wire diameters of this grade produce a medium percentage of open area.
Mud Screen	A wire cloth screen panel fitted with hooks for tensioning installed on shale shakers.
non-ferrous alloys	Non-pure metals containing no iron, such as copper, brass, aluminium, etc
OCW	Outside clamping width
off count	A mesh which has a greater number of wires per inch in one direction, usually the warp direction.
pen area	The ratio of open space area between the wires, to the total area of a given section of wire cloth, expressed as a percentage. Open area % = $(1-N*D)^2 * 100$, where N = Wires per inch or mesh and D = Wire diameter
opening	The dimension between adjacent parallel wires, usually expressed in decimal parts of an inch. Opening size = $(1-(N*D))/N$ where N = Wires per inch or mesh and D = Wire diameter See - "aperture" See - "space"
outside clamping width	Outside dimension (overall) of hooked edges on a screen panel. Also referred to as "OCW".Most original equipment manufacturers recommend an OCW of 1" less than the clear clamping width between the vibrator side plates.
utside dimension	The distance between the outside edges of a formed screen panel
overs	The product retained on the sieve. The fines is passing the sieve.
particle retention	The particle size that will be retained by a given mesh, usually expressed in microns.
pitch	The distance between centres of two adjacent wires in millimetres.
pitting corrosion	Localised corrosion resulting in small pits or craters in a metal surface.
Plain Weave	Woven wire cloth in which each warp and each weft wire passes over one and under the next adjacent wire in both directions.

Plain Dutch Weave	Dutch weave with each warp and shoot wire passing alternately over and under each successive wire.
plate, screening	Screening plate is a thin stainless steel with etched perforation - preferably made as a profile screen with conical perforations.
plugging	Near size particles trapped in screen apertures (openings) preventing passage of under size particles. See - "blinding"
porosity	The fractional void volume of the mesh.
pr file wire	Wire that has been drawn into a "wedge" (tapered) shape, which becomes progressively narrower from top to bottom.
Pr file Screen	A screen panel made up of profile wires with openings that become progressively wider from top to bottom. This increases dewatering efficiency and aids in screening material which might otherwise blind a screen surface. Also referred to as "wedge wire screen".
PZ	Reverse Hollander Plain Weave.
rectangular mesh	Wire cloth having a different number of wires in the warp and shoot (shute) usually less in the shoot, producing rectangular openings. See - "off count".
retention	The ability of wire cloth (wire mesh), as a filter medium, to prevent the passage of solids. It is expressed by the diameter, usually in microns, of the largest spherical solid particle that will normally pass through the screening surface.
RPD	Abbreviation for "Reverse Plain Dutch Weave".
Reverse Plain Dutch Weave	The arrangement of the warp and shute wire is reversed as compared to Plain Dutch Weave, providing a higher mesh count in the warp direction rather than the weft (shute) direction.
Rotary Screen	See - "trommel screen".
R tary vacuum filter	Trommel with filter cloth and support rotating in a tray with product product. The product built up a pre-coat and the filtered product is cut off the rotating drum by a knife and the water is drawn to the interior of the filter drum by a vacuum.
RotoSieve	Rotary screen
sieve	Metric openings, in a fixed ratio, assigned by the U.S. Bureau of Standards, based upon the number 18 sieve having an opening on one millimetre (0.039370"). The relation of consecutive numbered sieves is as one to the fourth root of two (or for every fourth sieve ratio is as one to two). Sieve numbers are arbitrary numbers and have no direct relationship to the number of meshes per inch.
sl tted openings	Wire cloth (wire mesh) with rectangular openings which allows the maximum open area and tends to prevent blinding or plugging of material. The warp mesh-count and wire size are indicated before the shoot (weft) mesh- count and wire size.
space	The actual clear opening or space between the inside edges of two parallel wires.
Space Cloth	Square mesh wire cloth which is designated by the width of the open space between the inside edges of two parallel wires.
SPW	Abbreviation for "Single Plain Dutch Weave".
square mesh	Wire cloth with the mesh count and wire diameter the same in both

	directions.
stranded weave	A twilled weave with multiple wires in both warp and the weft.
strainer	A fabricated assembly of woven wire cloth (wire mesh) designed for the removal of foreign particles from a stream of liquid or gas.
strainer cloth	A plain weave off-count mesh cloth with a high percentage of open area.
support screen	A heavy wire mesh utilised to support a finer mesh in filtration or straining.
S.W.G	British Imperial Standard Wire Gauge.
Testing Sieve	Fabricated circular frames available in stainless steel, brass or plastic fitted with wire mesh woven of brass, phosphor-bronze or stainless steel, having extremely accurate openings. Sieves are produced according to various standards, in the U.S. typically per ASTM E-11-70 in Europe according to DIN
Tinned Cloth	Wire cloth (wire mesh) woven of wire that has been coated with tin before the weaving process. Tinned cloth is generally available in "mill grade" wire diameters.
TRD	Abbreviation for "Twilled Reverse Dutch Weave"
Trommel Screen	A screen panel which is rolled to cover a cylinder, typically fastened by bolts, clamps or straps
Tyler	The W.S.Tyler Company, Cleveland Ohio.The Tyler company is the North American leader for Analytical Sieves of all sizes.Tyler had already standardized their sieves before ASTM, so in some cases, the Tyler number might be different than the ASTM number.
Twill Weave	Woven wire cloth in which each weft wire passes successively over two and under two warp wires and each warp wire passes successively over and under two weft wires.
Twill Dutch Weave	Each warp wire and each weft wire passes over and under the next to adjacent complementary wires, as in a normal "twill weave", except the warp wires are larger in diameter than the weft wires. This allows a greater mesh count in the weft direction. This weave pattern enables the weft wires to be woven more densely, and much smaller aperture sizes can be achieved.
warp	The wires running lengthways during weaving are referred to as WARP wires.
weft	The wires that run across the width of the cloth are referred to as WEFT or shoot wires.
wire	A solid wrought product that is long in relation to its cross section, which is square or rectangular with sharp or rounded corners or edges, or is round, a regular hexagon or a regular octagon, and whose diameter or greatest perpendicular distance between parallel faces (except for flattened wire) is less than 0.375 inch
wire cloth	A general term for material woven from metallic wires.
wire diameter	The diameter of wire before weaving.

Keywords: comparison conversion wire screen sieve cloth DIN ASTM

Millipore Filter Papers

Pure cellulose

Millipore filter papers are made of pure cellulose fibers and are available in a variety of grades and sizes. They meet ASTM standard E832 specifications for laboratory filter papers.
Selecting the optimal filter paper depends on the conditions of the application or analytical procedure. The most important criteria are: particle retention efficiency, fluid flow rate, and particulate loading.

Qualitative Filters

Containing nearly 100% alpha grade cellulose, these low ash (< 0.1%) filter papers are us analytical techniques to determine and identify particulate constituents.

Standard Filter Paper

Grade 101 (2.5 µm)
High retention of very fine particles.

Provides the maximum degree of particle retention in a qualitative filter. Excellent for filteri and finely grained precipitates, such as sulfates and oxide precipitates.

Grade 102 (3 µm)
High particulate retention.

Fastest qualitative filter for fine particle retention. Retention characteristics are nearly equi but filters twice as fast. Often used for boiler water analyses.

Grade 103* (6 - 8 µm)
Medium retention and flow rate.

Useful for separating precipitates, such as metal hydroxides.

Grade 104 (11 µm)
Medium retention and fast flow rate.

This grade is routinely used in qualitative analytical applications such as clarifying liquids, precipitates, soil analysis and seed testing procedures, air pollution monitoring and gas de

Grade 105 (20 - 25 µm)
Coarse particle retention and fast flow rate.

This grade is used in separation of coarse particles and gelatinous precipitates such as bi organic extracts. Ideal for fast filtration prior to analysis.

EXHIBIT B

General Purp se, Wet-Strengthened Filter Paper
Composed of the same alpha-grade cellulose fiber used in our standard filter papers, this wwetstrengthened by a small quantity of chemically stable resin added during production.

Grade 115* (25 μm)
Coarse particle retention and very fast flow rate.

This robust filter paper is routinely used in qualitative analytical applications involving larg particulate-heavy solutions.
**Also available folded in 125, 150, 185, 240, and 320 mm. Folded filter papers bring convenience and speed to high vo wasted individually folding filter papers; flow rates are faster due to larger filter paper surface area and minimal contact surface area also increases filter paper loading capacity.*

Quantitative Filters
Containing 100% alpha-grade cellulose, these ashless (< 0.007%) filter papers are used f analysis and sample preparation prior to instrument analysis.

Ashless Filter Paper
These ultra-pure filters are designed for use in a wide range of critical analytical filtration p

Grade 221 (2.5 μm)
Very high retention of fine particles.

This grade provides the maximum degree of particle retention in a quantitative filter. Exce extremely difficult and finely grained precipitates.

This grade is the standard for critical gravimetric analysis.

Grade 222 (3 μm)
High particulate retention.

Fastest quantitative filter for fine particle retention. Retention is similar to Grade 221, but v rate. Excellent for filtering extremely difficult and finely grained precipitates.

Grade 223 (8 μm)
Medium flow rate and retention.

Used in quantitative analytical applications such as gravimetric analysis, filtration of soluti absorption analysis, air pollution monitoring and gas detection.

Grade 224 (16 μm)
Medium retention and fast flow rate.

Used in quantitative analytical applications such as precipitates collection, soil analysis, in air pollution particle collection.

Grade 225 (20 – 25 μm)
Coarse particle retention and very fast flow rate.

The fastest ashless filter for coarse particulates. Used for analytical procedures involving l precipitates such as metal hydroxides.

Hardened Ashless Filter Paper

These highly robust filters are designed for use in a wide range of critical analytical filtratic are acid hardened for high wet strength and excellent chemical resistance. They offer an ((< 0.007%) ash content.

Grade 231 (2.5 µm)
High retention of very fine particles.

Used in gravimetric metal determinations in solutions that would weaken conventional filte

Grade 233 (8 µm)
Medium retention and flow rate.

Used in analysis of metals in acid/alkali solutions and in collecting hydroxides after precipi

Grade 235 (20 – 25 µm)
Coarse particle retention and very fast flow rate.

Used for protein determinations; for analyzing fiber in animal foodstuffs; for analyzing gela and for Si determination in steel and pig iron.

Specifications

	Grade	Retention (µm)	Ash (%)	Filter Speed Herzberg*	Filter Speed DIN**	Thickness (µm)	Weight (g/m^2)
Qualitative Filters							
	FP101	2.5	0.06	1500	160	155	80
	FP102	3	0.2	750	75	210	100
Standard Grade	FP103	6–8	0.06	240	48	170	80
	FP104	11	0.06	150	29	175	80
	FP105	20–25	0.06	50	11	220	90
Wet Strengthened	FP115	25	–	33	10	190	80
Folded	FP103V	6–8	0.06	240	48	170	80
	FP115V	25	–	33	10	190	80
Quantitative Filters							
	FP221	2.5	0.007	1500	40	150	80
	FP222	3	0.007	750	75	190	100
Ashless	FP223	8	0.007	480	48	160	80
	FP224	16	0.007	140	13	190	90
	FP225	20–25	0.007	50	11	200	90
	FP231	< 2.5	0.007	750	150	160	85
Hardened Ashless	FP233	8	0.007	150	23	195	85
	FP235	20–25	0.007	40	9	215	85

**Herzberg: sec/100 mL for 10 cm^2 at 10 cm head presssure*
***DIN53137: time (sec) to filter 10 mL*

Ordering Information

Compare	Description	Qty/Pk	Catalogue No.	Order
☐	Filter Paper Grade 101 flat 24 mm	100	FP101 024 00	add to orde
☐	Filter Paper Grade 101 flat 25 mm	100	FP101 025 00	add to orde
☐	Filter Paper Grade 101 flat 42.5 mm	100	FP101 042 00	add to orde
☐	Filter Paper Grade 101 flat 47 mm	100	FP101 047 00	add to orde
	Filter Paper Grade 101 flat 55 mm	100		

Chemical Engineers' Handbook

JOHN H. PERRY

Editor of First, Second, and Third Editions

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EXHIBIT C

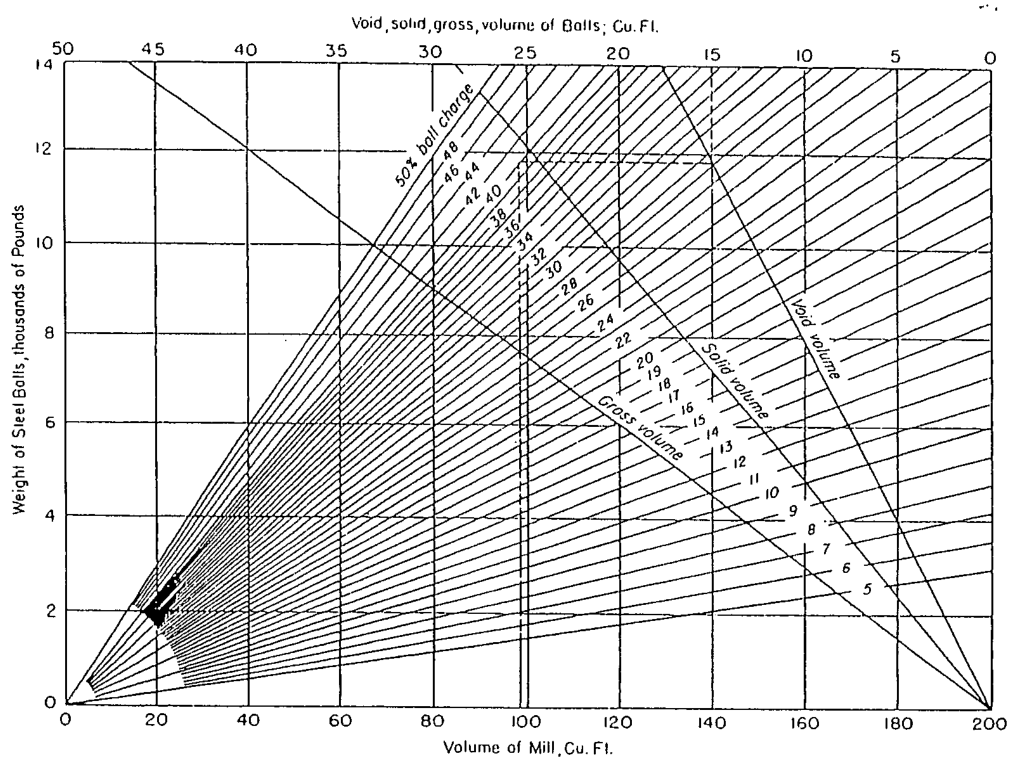

FIG. 8-28. Steel-ball charge relationships of ball mills.

ore charges yielded a little more selective grinding of the coarse particles than light charges. Best capacities were obtained with light charges, and slightly better efficiencies were obtained with heavy ore charges. To split hairs about efficiencies at various speeds the reader will have to study the table and be his own judge.

2. Some of the characteristics of dry-batch ball milling were unlike those of wet grinding. In the dry work, efficiency as well as capacity was best with the light ore charge. Power decreased with decrease in the amount of ore in the mill; in wet grinding it increased with a decrease in the amount of ore in the mill. In dry grinding high speed was more efficient than low speed.

3. In comparing wet and dry grinding the tests were paired so that all the set variables were the same, except pulp consistency (wet or dry). With an intermediate weight of ore charge, selective grinding was of the same degree; with a heavy ore charge, wet grinding was more selective, and with the light ore charge, dry grinding was more selective.

4. In comparing wet and dry open-circuit ball milling, wet grinding gave 39 per cent more capacity and 26 per cent more efficiency.

5. A small ball volume was not satisfactory in the overflow type of dry mill because too much ore built up in the mill. When building up of the ore was prevented by simulating the low-pulp-level mill, the small ball volume did good work.

6. With 60 per cent solids, pebbles the same size of balls did about the same type of work as balls when dolomite was ground, but they failed in selective grinding of chert. Pebbles gave about 35 per cent of the capacity and 81 per cent of the efficiency shown by the balls.

7. For hard and medium-hard ores, tetrahedrons were unsatisfactory for coarse grinding.

8. Very hard balls (Ni-hard) were better than ordinary balls; this was particularly so when the ore was very hard.

9. The efficiency of battered reject balls was about 11 per cent less than that of new spherical balls.

10. A ball mill as small as 19 by 36 in. duplicated the work of a plant-size mill. The tests led to the belief that, if each of a variety of mills, large or small, is run under the same conditions, and if each applies a unit of work to a unit of ore, the effect (comminution), as indicated by the products, will be the same; *i.e.*, the same relation between cause and effect will maintain.

Performance of Tumbling Mills. *Selection of Mill.* The selection of a ball- or rod-mill grinding unit is based on small-scale grindability tests (see p. 8-7). A procedure has been outlined by Michaelson (*Mining Tech.*, **9**, *Tech. Publ.* 1844, 1945). Laboratory ball-mill studies have shown capacity and power to be proportional to $D^{2.6}$, where D is mill diameter (see Gow, Campbell, and Coghill, *loc. cit.*). Capacity per unit of mill volume varies as $D^{0.6}$ [Fahrenwald, *Trans. Am. Inst. Mining Met. Engrs.*, **112**, 88 (1934)]. Capacity and power are directly proportional to mill length. These relationships also hold for commercial mills.

Capacity and Power Consumption. Theoretical considerations show the net power to drive a ball mill to be proportional to $D^{2.5}$, but this exponent may be used without modification in comparing two mills only when operating conditions are identical [Gow, Guggenheim, Campbell, and Coghill, *Trans. Am. Inst. Mining Met. Engrs.*, **112**, 24 (1934)]. The net power to drive a ball mill was found to be $P = [(0.5L - 1)K + 1][(0.5D)^{2.5}p]$, where L is the inside length of the mill, ft.; D is the mean inside diameter of the mill, ft.; p is the net power used by a 2- by 2-ft. laboratory mill under similar operating conditions; and K is 0.9 for mills less than 5 ft. long and 0.85 for mills over 5 ft. long.

An empirical relation for approximating the capacity of Foster Wheeler air-swept ball mills is $C = 0.008WNDsygz = 8000Ksygz$, where $K = WND \times 10^{-6}$ (private communication from Martin Frisch, Foster Wheeler Corp.). The horsepower required to drive these pulverizers for values of $K > 1$ is given approximately by $P = 49K^{0.9}$.

C is mill capacity, lb./hr.; W is weight of ball charge, lb.; N is mill speed, r.p.m.; D is average inside diameter to liner, ft.; P is net horsepower; and s, y, g, z are "effect factors" given in Table 8-14.

Table 8-14. "Effect Factors" for Foster Wheeler Ball Mill Capacity and Power Formulas

Feed size effect factor s, feed size, 100% through:					
Ring diameter, in.	1/16	1/8	3/4	1	2
s	1.2	1.13	1.0	0.97	0.9
Moisture effect factor y:					
Surface moisture, %	0	3	6	9	15
y	1.0	1.0	0.92	0.88	0.65
Grindability effect factor g:					
Grindability, Hardgrove index	30	40	60	80	100
g	0.43	0.55	0.73	0.83	1.0
Fineness effect factor z:					
Fineness % through No. 200 sieve	60	70	80	90	99
z	1.25	1.0	0.75	0.49	0.22

Performance of Proprietary Equipment. *Allis-Chalmers Mfg. Co.* The ball mill is used in the reduction of ores, wet or dry, through the No. 10 to No. 200 sieve range. Ball-mill feed size for very hard ores generally is less than ¼ in.; with moderate-hardness ores, the average is less than ½ in. Ball mills are built in diameters from 3 to 10½ ft. and length from one-half to twice the diameter, requiring drive motors ranging from 15 to 800 hp. Mills are charged with balls 1½ to 5 in. diameter, of cast iron, or forged or cast steel. Capacities range from 16 to 1400 tons/day based on medium-hard ore, single-stage, closed-circuit, ½-in. feed to minus No. 100 sieve product.

The *Compeb mill* has two or more compartments, designed to make a finished product in one operation, as in the grinding of cement clinker. Compeb mills are operated in either open or closed circuit, being more efficient with classification. Their application lies in the preparation of products 90 per cent or more able to pass a No. 200 sieve. They are considered a combination of the ball and *Ball Peb* mills used for dry grinding. The Compeb mill is built in single diameters from 3½ to 8 ft., with length up to five times the diameter. Two-diameter mills also are built. The primary compartment is charged with 2½- to 5-in. forged-steel balls; the finishing compartments have 1–2-in. balls. Drive motors range from 125 to 1250 hp. Capacities based on grinding average-hardness cement clinker in closed circuit with air classifiers, from 1-in. feed (about 5 sq. cm./g.) to a product of 1800 sq. cm./g. specific surface (approximately 95 per cent through No. 325 sieve), range from 450 to 3000 bbl./day.

The *Ball Peb mill* is a dry-grinding finishing mill used on cement clinker. Ball Peb mill feed is prepared by a *Preliminator mill* to 95 per cent minus No. 20 sieve. The product from the Ball Peb is obtained from air classifiers which close-circuit the mill, and it averages 1800 sq. cm./g. specific surface (approximately 95 per cent minus No. 325 sieve), or finer. Capacities range from 850 to 4200 bbl./day. Ball Peb mills are built 3 to 8 ft. in diameter and in lengths four times the diameter. Longer mills are multicompartment, the charge in each compartment having a different size in order to grind the feed to that compartment more efficiently. The charge consists of forged-steel balls ¾ to 1½ in. in diameter. Drive motors range from 40 to 900 hp.

The *Allis-Chalmers rod mill* is a wet or dry grinder operating most efficiently in the size range from No. 10 to No. 35 sieve size. Less efficient operation results in the No. 35 to No. 65 sieve range, where operation overlaps the ball mill. Rod mills are best applied for primary grinding where the production of extremely small particles or sliming is undesirable. Large-diameter rod mills are used as intermediate stage of crushing and in instances have effectively displaced crushing rolls for preparing ball-mill feed. Such applications are warranted only for medium-hard and soft ores. It is a selective grinder, particularly on heterogeneous ores. Rod mills will receive ⅞-in. and larger feed of moderate-hardness ores; but extreme wear on feed-end mill liners and differential wear on rods result, requiring larger-diameter rods, which are less efficient. Rod mills are built from 3 to 9½ ft. diameter, length equal to or greater than the diameter, with a maximum of about 16 ft. Overflow and peripheral discharge mills are used. The grinding medium consists of steel rods 2 to 4½ in. diameter, a few inches shorter than the mill. Drive motors from 15 to 600 hp. are used. Capacities on medium-hard ores through No. 35 sieve range from 50 to 1600 tons/day in open circuit.

The F. L. Smidth & Co. Tumbling mills built by this company find their principal use in cement plants; the best known types are the *Kominuter*, *Unikom*, *Unidan*, and *Pyrator*. For dry operation, the mills usually are fed by a table or cradle feeder; for wet operation, feeding is from a slurry trough by means of an orifice or scoop. The mills may have silex (stone) or *dragpeb* (steel) linings. Flint pebbles are used with silex linings and *cylpebs* (a cylindrical grinding medium) with dragpeb lining.

The *Kominuter* is a screen-type mill operated in closed circuit, usually the first in a two-stage unit where reduction is carried only to the size of a rather coarse mesh, which is fed to tube mills for final grinding. In wet grinding, water is added at the feed hopper, passing the slurry produced through the mill as in dry grinding.

The *Unikom* is a four-compartment mill, a section with large diameter forming the first, or granulating, compartment, with a section of small diameter divided into three compartments. The enlarged section is fitted with liner plates and a special screening arrangement which bypasses fines to the first compartment in the second section and returns oversize to the granulating compartment for further reduction. The first chamber of the second section is equipped with grinding balls, the following compartments with cylpebs, graded downward in size.

The *Unidan* mill is a compartment mill, with three or more compartments, equally well suited for wet and dry grinding. Balls are used in the first compartment, which is also equipped with liners. The compartments for fine grinding are equipped with special rings and steel-alloy lining and with cylpebs graded downward in size toward the discharge end. An added feature of the mill is a special screen arrangement mounted within the mill body; the material does not leave the mill body until finally discharged at the outlet end.

The *Pyrator* mill is used for granulating, pulverizing, and drying damp material in a single unit; it consists of a two-compartment tube mill comprising a ball chamber with liners; a combined screening and ball-separating partition, and a fine-grinding chamber with special ring and alloy lining and cylpebs as the grinding medium. The steel balls are heated and have the double capacity of acting as grinding medium and supplying the heat required for drying. Hot air circulates around the mill body, which is provided with a jacket to retain the hot air in closed circuit, and the mill is provided with means for removing the balls, which are elevated, heated in a hot-air furnace, and returned to the feed end. When the material does not contain an excessive amount of moisture, this unit is very efficient, compact, and economical.

The Mine and Smelter Supply Co. The *Marcy* ball mill (Fig. 8-26), used extensively for wet and dry grinding of ores, will take feed as coarse as 2 in. and grind to No. 200 sieve size in closed circuit with a classifier. Discharge grates are used to give a rapid change of mill content with a high circulating load. Performance is given in Table 8-15. The *Open End rod mill* is designed for a

Table 8-15. Performance of Marcy Ball Mills

Size, ft.	Ball charge, tons	Hp. to run	Mill speed, r.p.m.	Capacity, tons/24 hr. (based on medium-hard ore)								
				No. 8 sieve*	No. 20 sieve	No. 35 sieve	No. 48 sieve	No. 65 sieve	No. 80 sieve	No. 100 sieve	No. 150 sieve	No. 200 sieve
				20% −200	35% −200	50% −200	60% −200	70% −200	80% −200	85% −200	93% −200	97% −200
3 × 2	0.85	5– 7	35	19	15	12	10	8	6½	5	4	3
4 × 3	2.73	20– 24	30	80	64	53	45	36	28	22	18	14
5 × 4	5.25	44– 50	27	180	145	120	102	82	63	51	41	32
6 × 4½	8.90	85– 95	24	375	300	250	210	170	135	105	85	66
7 × 5	13.10	135–150	22½	640	510	425	360	290	225	180	145	113
8 × 6	20.2	220–245	21	1100	885	735	625	500	390	310	250	195
9 × 7	30.0	345–380	20	1800	1450	1200	1020	815	635	505	410	315
10 × 10	56.50	700–750	18	3680	2960	2450	2100	1700	1325	1050	850	655
12 × 12	90.5	1260–1345	16.4	7125	5725	4750	4070	3290	2570	2035	1650	1275

* Sieve through which substantially all the material can pass.

heavy, revolving rod mass and a discharge pulp level below the rod mass, giving rapid passage through the mill. A specially designed discharge housing mounted independently of the mill and with a hinged door permits easy access for inspection, relining, and charging of rods. It takes a 1-in. feed, reducing it in one pass to No. 8 to No. 20 sieve size. The uniform discharge product results from the fact that the low-pulp-line mill does not make a displacement product, since the difference in elevation between feed and discharge ensures rapid removal of the finished product. For a finer product of No. 60 to 80 sieve size, the mill is closed-circuited with screens or classifiers. Performance on 1-in. medium-hard material is shown in Table 8-16.

Table 8-16. Performance of Marcy Rod Mills

Size, ft.	Rod charge, tons	Hp. to run	Mill speed, r.p.m.	Capacity, tons/24 hr.				
				No. 8 sieve	No. 20 sieve	No. 35 sieve	No. 48 sieve	No. 65 sieve
2 × 4	0.9	4– 6	38	20	15	12	10	7
3 × 6	3.6	18– 22	30	105	80	65	50	40
4 × 8	7.6	44– 48	25	240	180	145	120	90
5 × 10	14.5	85– 95	21	525	390	315	260	195
6 × 12	24.1	135–150	17½	855	640	510	425	320
7 × 15	42.1	225–250	15	1600	1200	965	800	600
8 × 12	45.4	230–250	13.2	1675	1250	1000	830	625
9 × 12	54.7	310–340	12.5	2240	1680	1350	1115	835

Hardinge Co. The Hardinge Conical mill, shown in Fig. 8-27, is used extensively for both wet and dry grinding in open and closed circuits. The conical mill is similar to the cylindrical mill in that it consists of a drum rotating about its horizontal axis and operating in much the same way, but unlike the cylindrical mill, it has conical ends instead of straight ends. Ball segregation takes place and roughly proportions the energy to the work performed, the large balls assembling in the cylinder at the feed end of the mill where the diameter is largest, while the smaller balls arrange themselves in decreasing sizes toward the discharge end of the mill.

Hardinge Ball Mills are lined with metallic liners of the wedge-bar type, or of the wave or ribbed type. The wearing bar of the wedge-bar type of lining serves the purpose of lifting the mass of balls and material as well as holding the liner plates in place. *Hardinge Pebble Mills* may be lined with adamant silica, silex, porcelain, or any other non-metallic lining required for the operation. Hardinge wet grinding mills are supplied with discharge arrangements for high, medium, or low pulp levels, the use of which depends on the particular problem under consideration. A suitable grate is used which will permit carrying a maximum ball charge and pulp load in a given-size mill and it also keeps the balls from spilling out of the mill and prevents an accumulation of tramp oversize at the discharge end of the mill. For dry grinding a vertical grate with low-pulp-level discharge vanes is used.

Mill feeders attached to the feed trunnion of the conical mill and used to pass the feed into the mill without backspill are of several types. A feed chute is generally used for dry grinding, this consisting of an inclined chute sealed at the outer edge of the trunnion, and down which the material slides to pass through the trunnion and into the mill. A screw feeder may also be used when dry grinding, consisting of a short section of screw conveyor which extends part way into the opening in the feed trunnion and conveys the material into the mill. For wet grinding, several different types of feeders are available; the scoop feeder attached to and rotating with the mill trunnion and which dips into a stationary box to pick up the material and pass it into the mill; a drum feeder attached to and rotating with the feed trunnion, having a central opening into which the material is fed, and an internal deflector or lifter to pass the material through the trunnion into the mill; or a combination drum and scoop feeder, where the new feed to the mill is fed through the central opening of the drum while the scoop picks up the oversize being returned from a classifier to a scoop box well below the center line of the mill. The mill feeder must be able to handle any quantity of material which the mill may be capable of grinding, and in addition, a circulating load which may be as high as 1000 per cent of the new feed rate. The dry-grinding performance of Hardinge mills on materials of average hardness is given in Table 8-17.

Table 8-17. Performance of Hardinge Ball and Pebble Mills

Size of mill*	Approx. weight, lb.			Speed, r.p.m.	Hp. to run	Capacity, tons per 24 hr.		
	Mill	Lining	Balls			1½ in. to 90%, through No. 100 sieve	Closed circuit with air classifier: ¾ in. to 90%, through No. 200 sieve	Closed circuit with air classifier: ½ in. to 98%, through No. 325 sieve
2′ × 8″	900	375	400	40	1	4	3	1½
4½′ × 24″	8,100	5,400	4,500	28	25	48	36	18
6′ × 48″	17,000	12,000	15,000	25	70	144	108	54
8′ × 48″	27,000	23,000	31,000	21	160	360	252	126
10′ × 66″	51,000	35,000	65,000	18	350	840	600	300
			Pebbles			Open circuit, ½-in. to No. 10 sieve size	Closed circuit, ½ in. to No. 48 sieve size	
2′ × 8″	900	400	175	42	½	2	1½	
4½′ × 24″	8,000	2,300	2,400	30	12	15	9	
6′ × 48″	12,000	5,000	8,500	27	30	54	36	
8′ × 48″	17,000	14,000	14,000	24	62	120	84	
10′ × 66″	32,000	20,000	28,000	18	160	336	216	

* Diameter by length of cylindrical section.

Regulating feeders are built in two basic designs, *i.e.*, constant-volume and constant-weight feeders. Typical of the constant-volume type is the *Hardinge Disc Feeder*, which consists of a circular hopper which is generally fastened to the bottom of the feed bin, the feed sliding from the hopper onto the center of a revolving disk, and